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GB 2040182A
GB 1598172
FR 2384945A
GB 1598099
FR 2396163A
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(54) Periodic rejuvenation of a catalyst filter

(57) Method for filtering combustible particles from an exhaust gas stream, and for periodically rejuvenating the filter bed by incinerating retained particles. At least a portion of an engine's exhaust gas stream is initially preheated to raise the filter's catalytic segment to a predetermined "lightoff" temperature. A supplementary fuel flow e.g. of H_2, propane, diesel fuel, kerosene, or alcohol is then introduced to the catalyst segment which, being at "lightoff" temperature, will cause the supplementary fuel to react. Subsequent to the initiation of this oxidation reaction, further energy input to increase the exhaust gas to "lightoff" temperature, can be reduced or cut-off without effecting the continuing particle incineration rate.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig. 1.

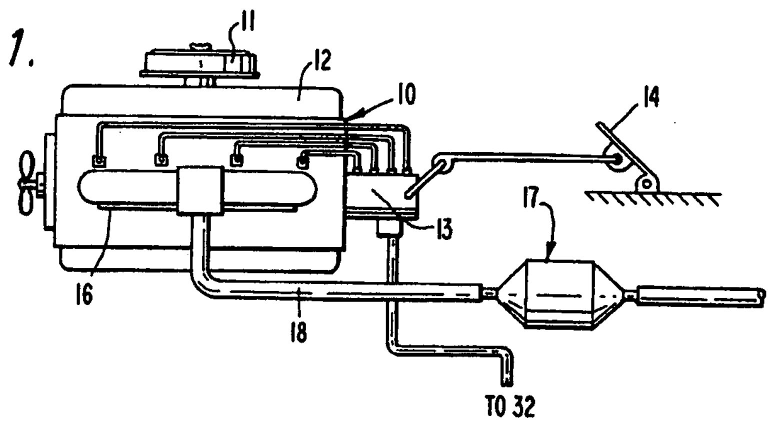


Fig. 2.

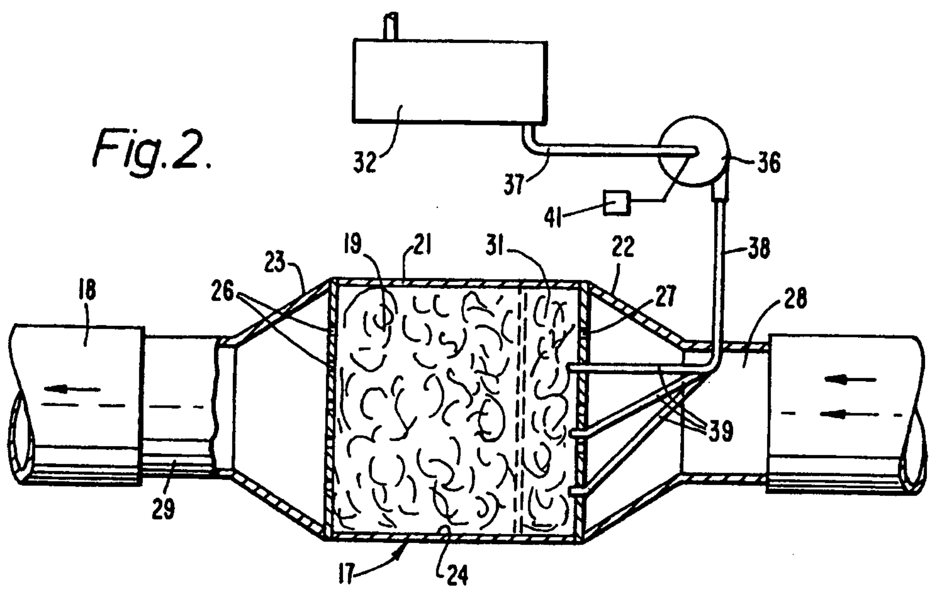


Fig. 4.

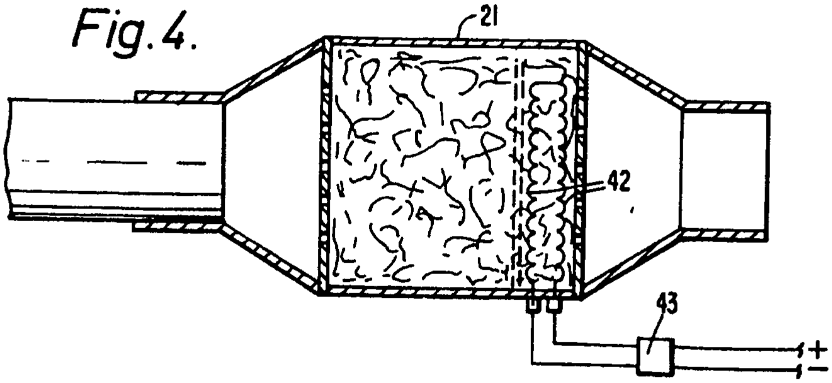
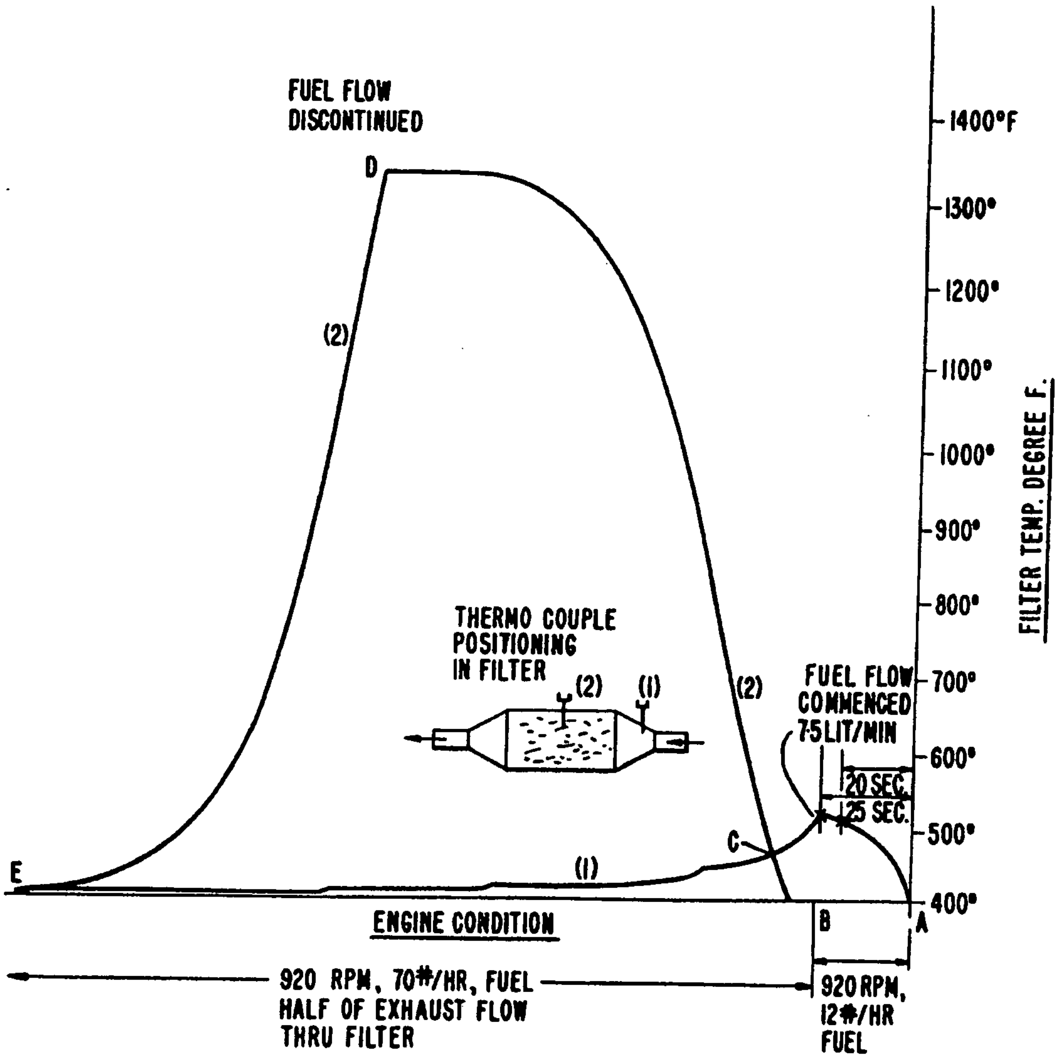


Fig. 3.



EXHAUST TEMPERATURE PROFILE IN FILTER
CATALIST BED AFTER FUEL (PROPANE)
INTRODUCTION.

SPECIFICATION

Periodic rejuvenation of a catalyst filter

With any internal combustion engine it is desirable to treat exhaust gases so that they can be safely discharged into the atmosphere. In some engines, particularly of the diesel type, among the most prevalent operating problems is the presence of particulates which are carried in the exhaust gas stream.

Primarily, the particulates are normally bits of carbon. They result from incomplete combustion of the hydrocarbon fuel under certain engine operating conditions. However, the operating efficiency of the engine is also a contributing factor to the amount of carbon produced.

The presence of relatively large amounts of carbon particles in any exhaust gas stream is evidenced by a dark, smoky, undesirable effluent. Such smoke is not only offensive aesthetically; in large quantities it can be unhealthy.

Means have been provided and are known to the prior art, for the elimination or minimization of the particulate content in exhaust discharge streams. However, it has been found that while the particulates can be eliminated by a suitable filter of proper construction, eventually the latter can become saturated and/or inoperable due to excessive particulate accumulations.

It is further known that the overall engine exhaust gas treating process can be expedited. This is achieved not only by passing the hot gas stream through a filter medium, but by providing the filter with a catalyst which will promote combustion of retained particles.

It should be appreciated that the generation of carbon particles is prevalent under all diesel engine operating conditions. It is further appreciated that the quantity and quality of an exhaust gas stream created in any internal combustion engine will vary in accordance with the operating characteristics of the engine.

For example, the temperature range experienced by the diesel exhaust gas stream can vary between slightly above ambient air temperature, and temperatures in excess of 1200°F. When the exhaust gas is hot enough, carbon particles trapped in a filter will be combusted. However, engine operating conditions at which this rejuvenation can occur is not always attainable in diesel passenger cars.

Where it is found that an engine continuously operates under such circumstances that particulates are continuously produced and accumulated in the filter, the particulate trapping filter bed must be rejuvenated with a degree of consistency.

When the exhaust is sufficiently hot, rejuvenation will consist of merely introducing the hot exhaust gas stream, containing sufficient oxygen, into the filter bed to contact and ignite or incinerate retained carbon particles. The combustion of any large carbon accumulation can, however, produce temperatures in excess of that of the exhaust gas. The result is that at such excessive temperatures, the filter bed is susceptible to thermal shock, damage or distortion.

Toward achieving a satisfactory or controlled rate of carbon removal from an exhaust gas stream without incurring damage to the filter, the unit presently disclosed is provided to illustrate the method. The instant system thus constitutes in brief, a reaction chamber or filter bed which comprises in part a catalytic segment through which at least a portion of the exhaust gas stream flows. This catalyst surface can be incorporated uniformly within the particle trapping bed, or can be disposed only at the bed upstream end.

To assure that the main filter bed or beds remain functional in spite of engine operating conditions, the exhaust gas stream, or at least a portion thereof, can be preheated. Initial preheating can also be achieved within the catalytic segment through which the exhaust stream is passed.

Initial heating of the stream is achievable in any of several ways to raise the exhaust gas temperature at least to the "lightoff" temperature of the catalyst. After the catalyst "lightoff" temperature is achieved, supplementary fuel is introduced. As oxidation of the supplementary fuel commences, preheating of the exhaust gas can be moderated or discontinued without quenching the oxidation reaction.

In summary, the main filter bed will be regularly and at periodic intervals, purged or rejuvenated. Such treatment, if repeated at predetermined times will preclude carbon accumulations which, if not disposed of, might otherwise lead to thermal stress or damage to the bed at such time as the accumulation is combusted.

It is therefore an object of the invention to provide a filter of the type disclosed. The filter is capable of retaining combustible particulates from an exhaust gas stream, and of being periodically rejuvenated by incinerating the particulates.

The invention makes it possible to provide a particulate filter of the type disclosed which is capable of removing solid elements from an exhaust gas stream while permitting periodic rejuvenation of the filter element.

The invention also makes it possible to provide a filter unit for an internal combustion engine, which filter is periodically rejuvenated by introduction of a supplementary fuel to the filter bed while the engine is operating at conditions that do not result in exhaust gas temperatures sufficiently high to initiate combustion of the supplementary fuel.

The invention makes it possible to provide an exhaust gas treating unit which is capable

of removing particulates from an exhaust gas stream without jeopardizing the integrity of the filter bed by subjecting the latter to thermal shock or damage.

IN THE DRAWINGS

Figure 1 illustrates a diesel engine of the type contemplated with which the present smoke filtering system cooperates.

Figure 2 is an enlarged view in cross-section, of the filter element of Fig. 1.

Figure 3 is a graphical illustration of the disclosed exhaust gas treating method.

Figure 4 is similar to Fig. 2, with the addition of an electric heater.

To facilitate description of the present method, an internal combustion engine 10 or other source of gas, will be considered to be of the diesel type. In the latter, air is sequentially introduced from an air filter 11, by way of manifold 12 to the various combustion chambers. Diesel fuel is therafter injected in controlled amounts into each combustion chamber from a fuel pump 13. Fuel flow rate is regulated by control linkage 14.

The hot exhaust gas stream is led from exhaust manifold 16, and conducted through an exhaust pipe 18 to a smoke filter 17. Although a sound absorbing muffler could be inserted into the exhaust pipe, such an element is ancillary to and not essential to the instant system and method of operation.

The exhaust gas stream, subsequent to leaving exhaust manifold 16, will usually be at a temperature within the range of about 200 to 1200°F. The precise temperature will depend on the operating conditions of the engine.

For example, at low loads and idle, exhaust gas will be relatively cool or only moderately heated. Consequently, as the particle laden exhaust gas stream enters filter 17, the particulates will be retained along the many diverse passages within the filter bed 19.

While the exhaust gas is comprised primarily of a combination of gases, it usually embodies sufficient oxygen content to support at least a limited degree of combustion within the stream itself.

Referring to Fig. 2, in one embodiment, filter 17 comprises an elongated metallic casing 21 having opposed end walls 22 and 23 which define an internal reaction chamber 24. The latter chamber is occupied to a large extent by at least one filter bed 19, formed of material particularly adapted to provide a plurality of irregular flow passages therethrough.

The function of bed 19, or similar beds which are arranged to occupy chamber 24, is to define a series of passages along which the exhaust gas will flow. During such passage, particulate matter carried on the exhaust stream will be retained on the various passage walls.

Bed 19 can be formed preferably of a metallic mesh-like mass such as steel wool, metal fibrils or the like, which mass is shaped to substantially fill reaction chamber 24.

Bed 19 can be optionally supported at its upstream and downstream ends by perforate panels 26 and 27 or other similar rigid transverse members. The latter are positioned at casing wall 21 to support the one or more beds 19 therein particularly when the latter become weakened from heat.

the filter upstream wall 22 is provided with inlet port 28 for introducing exhaust gas to the upstream side of bed 19. In a similar manner wall 23 is communicated with a discharge conduit 29 to carry away particle-free gases which leave bed 19.

To best achieve the gas filtering action, bed 19 can be comprised as noted of a suitable gas pervious medium or matrix which is capable of retaining solid particulate matter from the exhaust gas stream. To facilitate the incineration of the retained particles, exhaust gas entering the bed will initially heat the catalyst containing segment thereof by contact. With the catalyst portion then raised to "lightoff" temperature, supplementary fuel can be introduced thereto.

The catalyst bed now at a temperature of about 450°F to 550°F will receive a fuel injection. The mixture of fuel, whether in liquid or gaseous form, together with the combustion supporting oxygen in the exhaust stream, will thereby be ignited when in contact with the catalyst surface.

At such time as the fuel mixture commences to burn, the catalyst bed will no longer require preheating energy. As the combustion of the fuel mixture continues, the bed will gradually rise in temperature to about 1000° to 1300°F.

As the exhaust gas stream enters the main filter bed 19 from the catalyst segment, the gas will be at an elevated temperature approximating that of the catalyst bed. In such an elevated temperature environment, particulate matter retained on the main filter will be incinerated, and bed 19 will be left relatively particle-free.

In accordance with the invention, an apparatus capable of practicing the method provides that the forward or upstream end of filter bed 19 incorporate a catalyst segment or catalyst bed 31. The latter includes a matrix or filter media having a thin layer of an oxidizing catalyst material deposited on the surface thereof. Said layer is capable of enhancing oxidation of a supplementary fuel as the latter is mixed with the exhaust gas. This preheating segment or chamber 31 of the filter is preferably physically a part of bed 19, preferably less than one-half by volume. It can, alternatively be a discrete segment of the bed.

Preheating segment 31 is positioned in the forward or upstream portion of casing 21,

extending transversely thereof to contact the entire incoming exhaust gas stream as soon as the latter enters reaction chamber 24.

Toward achieving controlled preheating of the exhaust gas stream, a fuel injection system is provided. The latter embodies primarily a source 32 of a supplementary combustible fuel together with means for inserting a measured amount of said fuel into preheating segment 31 of filter bed 19. Said fuel source 32 can be in either finely atomized liquid, or in gaseous form to achieve the desired preheating function.

The supplementary fuel source 32 can, in one embodiment, be the diesel fuel for powering internal combustion engine 10. Alternatively it can be a compressed, hydrocarbon gas such as propane, hydrogen or the like which is carried on the vehicle for the purpose of periodic injection into preheating segment 31.

In brief, the supplementary fuel utilized can be any one of a number of known volatile substances, hydrocarbon or otherwise such as kerosene and various alcohols. The fuel should, however, be capable of reacting within catalyst chamber 31 to achieve the desired combustion.

In one form, the supplementary fuel injection system is comprised of a pump 36, or other suitable metering means, having inlet side 37 communicated with fuel source 32. Pump 36 in turn is communicated with an injector 38 which can be provided with one or more atomizing nozzles 39. The latter are arranged to inject fuel into the exhaust gas upstream of catalyst-containing preheating chamber 31.

Operationally, when pump 36 is periodically actuated by the control means 41, a measured amount of combustible, fluidized fuel will be introduced by way of nozzles 39 directly into the heated exhaust stream which enters chamber 31. In the latter, the supplementary fuel gas mixture will oxidize in the presence of the oxidizing catalyst.

As illustrated in Fig. 3, supplementary introduction of fuel, according to the invention, will be maintained only for a sufficient time period to burn carbon particles from filter bed 19. Thereafter, the fuel injection is terminated to allow a normal flow of exhaust gas to pass through the filter bed.

However, and as herein noted, prior to the supplementary fuel being oxidized, catalyst segment 31 in which the exhaust gas is first received, is brought to a high enough temperature such that an oxidation reaction will be initiated upon contact between the supplementary fuel and the catalytic surface. When the catalyst surface has been raised to at least the "lightoff" temperature, the supplementary fuel will not go unburned within segment 31.

Heating of bed segment 31 to the desired "lightoff" condition other than by introduction of a supplementary fuel, can be achieved in any of several ways. The preferred method for example is by the natural action of the engine itself resulting in sufficiently high exhaust temperatures. Often, however, in normal use, this is seldom achieved, and an additional heat input method is required.

One such method, and referring to Fig. 4, utilizes an electrically heated element 42 which is disposed at the upstream side of filter bed 19. In such arrangement, which is embodied in the filter of Fig. 2, heating element 42 is disposed transversely of casing 21 at the filter inlet end. It could, however, in the alternative, be positioned anywhere upstream of filter bed 19.

Heater 42 is most readily connected directly to the engine electrical system such as a battery or similar power source. Thus, at predetermined timed intervals, heater element 42 will be actuated by a timer 43 or other electrical switching means which is disposed between the heater element and the vehicle's battery.

Referring to the chart of Fig. 3, after a desired period (A to B) of preheating, catalyst segment 31 will be raised to a desired "lightoff" temperature, 520°F, and the heating discontinued. The latter step, although preferably achieved through a set time period, can be accomplished as well by use of a temperature monitoring thermocoupled disposed within segment 31 or bed 19.

In any event, the initial exhaust gas heating will be continued only until the condition within segment 31 reaches the "lightoff" temperature at which the supplemental fuel-gas mixture will ignite upon contact with the hot catalyst surface.

Initial preheating of segment 31 as noted can also be accomplished through the facility of adjusting operation of the internal combustion engine. This is achieved most readily by choking the engine operation whereby the temperature of the exhaust gas entering the catalyst segment 31 will be temporarily elevated.

In the example of the disclosed method, as shown in Fig. 3, the graph shows the temperatures which are established within a filter body at two separate points. These temperature check points are prior to the filter bed 19 (point 1), the second point (2) being within the filter bed 19 where oxidation of the injected supplementary gas is most felt.

In Fig. 3, point A shows the temperature within the forward or inlet port 28 of the filter and reflects an engine exhaust gas temperature of approximately 400°F.

To initially raise the catalytic segment 31 to the desired "lightoff" temperature, i.e. approximately 500°, engine operation is initially altered by choking, whereby the exhaust temperature will be raised to about 520°F (point B). As herein noted, this initial heating of the

catalytic segment by exhaust gas can alternatively be achieved through use of an electrical heater, or by increasing the engine fuel injection rate, or the engine intake air throttling.

After an initial preheat lasting for approximately 20 seconds, during which the temperature within filter compartment 31 reaches approximately 520°F, the introduction of propane into said segment 31 will be commenced. Thereafter, as propane contacts the heated catalytic surface within 31, the temperature within filter bed 19 will increase at a relatively rapid rate. This segment of the graph indicates not only the burning of the introduced supplementary propane, (point C to D), but also the incineration of the carbon particles which had been retained on the walls of filter bed 19.

At a maximum temperature of approximately 1350°F which is maintained for approximately one minute, introduction of propane is discontinued. Therafter, the temperature in filter bed 19 (at point 2) will rapidly decrease (point D to E) in view of the lack of fuel, as well as the lack or carbon particles to be incinerated. The filter bed 19 temperature will then stabilize to a temperature of approximately 400° which is established by the temperature of the exhaust gas stream.

As herein noted, periodic heating of the filter bed 19, which is preceded by the preheating of the catalytic segment 31, is followed on a timed basis. The termination of said preheating can also be achieved by monitoring the temperature within filter bed 19 through a thermocouple or the like. The latter as herein noted could be so positioned to regulate either the operation of electrical heater 42 within filter bed 19, or by other means which will regulate the temperature of the exhaust gas at the upstream end of the filter bed.

Other modifications and variations of the invention as hereinbefore set forth can be made without departing from the spirit and scope thereof, and therefore, only such limitations should be imposed as are indicated in the appended claims.

CLAIMS

1. A method for treating a hot exhaust gas stream from an internal combustion engine which burns a hydrocarbon fuel, which exhaust stream carries combustible particles from the engine, said method including the steps of:–

passing the exhaust gas stream through a gas pervious particle retaining filter bed, comprising a matrix, at least a segment of the latter embodying a catalytic material, whereby said particles are retained within the filer bed and the particle-free gaseous stream is passed therethrough,

periodically purging said filter bed of retained particles by:

initially preheating at least a portion of the exhaust gas stream to a temperature at which a supplementary fuel will oxidize upon contact of said supplementary fuel with said catalytic material,

introducing a flow of said supplementary fuel into the preheated catalytic segment to initiate combustion in the filter bed of supplementary fuel and retained particles, and

discontinuing the initial preheating of said portion of exhaust gas stream while maintaining the introduction of fuel to the catalytic section, thus sustaining oxidation in the latter until said filter bed is free of retained particles.

2. A method as claimed in Claim 1, wherein said catalytic material is disposed substantially throughout said filter bed.

3. A method as claimed in Claim 1, wherein said catalytic segment is disposed only at the upstream end of said filter bed to contact exhaust gas prior to entry of the latter into the filter bed.

4. A method as claimed in Claim 1, wherein said catalytic material is in the form of a thin layer disposed on the matrix.

5. A method as claimed in Claim 1, wherein said segment of the filter bed embodying a catalytic material, comprises less than approximately one-half by volume of the particle retaining filter bed.

6. A method as claimed in any preceding Claim, wherein said supplementary fuel is introduced to the catalytic segment in liquid form.

7. A method as claimed in any of Claims 1 to 5, wherein said supplementary fuel is introduced to the catalytic segment in gaseous form.

8. A method as claimed in any of Claims 1 to 5, wherein said supplementary fuel is chosen from the group comprising diesel fuel, kerosene and alcohol.

9. A method as claimed in any of Claims 1 to 5, wherein said supplementary fuel is chosen from the group comprising hydrogen and propane.

10. A method as claimed in any preceding Claim, wherein said catalytic material comprises an oxidation catalyst.

11. A method as claimed in any preceding Claim wherein said filter bed is periodically purged of retained particles as a function of the time during which the internal combustion engine operates.

12. A method as claimed in any preceding Claim, including the steps of: regulating the flow of supplementary fuel introduced to the catalytic segment, whereby to regulate the temperature within the filter bed.

13. A method as claimed in any preceding Claim, including the step of: monitoring the temperature within the filter bed, and regulating the flow of supplementary fuel which is introduced to the catalytic segment thereof in

response to said filter bed temperature.

14. A method for treating a hot exhaust gas stream from an internal combustion engine, substantially as hereinbefore described with reference to the accompanying drawings.

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